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SOC INDUCED EFFECTS ON SOIL PERMEABILITY

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ABSTRACT

Raichur district is located in the northern region of Karnataka state, which is drought prone and falls in the arid tract of the country. The climate of the district is characterized by dryness for the major part of the year and a very hot summer. The low and highly variable rainfall renders the district liable to drought. Hence, increasing the soil water-holding capacity has been a major issue in this area. This study was conducted to find the threshold limit of SOC with respect to soil porosity and infiltration of four of the arid soils obtained from organic farms. Wastes like humus, pressmud, bagasseash and flyash were used as a source of SOC to amend with the soils. SOC inputs were volumetrically made up to 70% in the increments of 10% of the soil columns. Analyses were made by triplicate columns in three different phases based on the mode of application of SOC. The highest porosities were 72.54%, 69.27%, 71.53 and 68.56% similarly highest infiltration observed were 48.33%, 77.37%, 55.56% and 84.12% for black cotton, red marshy and mountainous soils respectively. The positive relation between threshold limit SOC, WHC, porosity and infiltration were obtained.

KEYWORDS: WHC, Porosity, Infiltration, Aggregation and SOC

INTRODUCTION

The reservoir of water in the soil is replenished by the process called infiltration, the entry of water into the soil. Infiltration is very important in irrigation since the goal is to supply water to the root zone to meet plant needs. In most cases, the goal is that all of the applied irrigation and rain enters the soil; thereby minimizing the amount of water that runs off the soil surface. Two things allow infiltration, capillarity and gravity. During the initial stages of a water application, the capillary forces dominate water movement into the soil. Capillary forces work equally in all directions. Thus, the capillary forces pulling water into the soil are the same in the horizontal and vertical directions. As time progresses, the capillary forces diminish and gravity becomes the dominant force. When water is applied at a rate faster than can be absorbed by the soil the water will not infiltrate and is referred to as potential runoff. Factors influencing the infiltration rate are soil texture, surface sealing, soil cracking and the method of water application. If the soils were uniform with depth, and if surface sealing did not occur, the steady-state infiltration rate would be equal to the permeability or saturated hydraulic conductivity of the soil. Surface sealing occurs in both surface and sprinkler irrigation. With surface irrigation the shearing effect of the flowing water will cause the aggregates on the soil surface to decompose into smaller aggregates and individual particles which tend to form a thin layer with low permeability on the soil surface forming a surface seal. Protection of the soil surface by organic matter can help prevent surface seal development by dissipating the energy of the falling drops. Another factor that has a large influence on infiltration is soil cracking. Soils that contain fine soil particles (clays) shrink when drying and swell during wetting. These cracks have a tremendous affect on the initial infiltration rate of a soil as water flows freely into them. The cracks swell shut as the soil becomes wet which causes a rapid decrease in the infiltration rate. Soil organic carbon in long-term arable soils in many parts of the world is declining and this trend is likely to cause deterioration of soil structure and workability.

The continuous decomposition of organic matter (OM) in cultivated soils of arid and semiarid regions may lead to soil degradation with a consequence of inability to ensure a sustainable production. In recent years, the use of organic amendment other than traditional manure has become popular and efficient for the improvement and/or restoration of soil OM. The application of organic wastes, and particularly composted municipal solid waste and sewage sludge, could be a way of solving this problem. However, it could lead to phytotoxic levels of heavy metals in soils (Hynes and Naidu, 1998; Hagreaves et, al. 2008). Organic matter can improve a range of soil physical and mechanical properties. These include compactability (Ball et, al. 2000; Mosaddeghi et, al. 2000), soil strength, water content (WC) range for tillage operations or workable range (Dextar and Bird, 2001) and soil physical quality in general. These effects are usually such that an increased content of OM results in improved soil physical properties, i.e. soil that is less compactable and more easily tilled, and has higher workable range. Additions of organic fertilizers result in increased soil organic content (SOC) (Hynes and Naidu, 1998). Previous investigations have consistently found that incorporating farm yard manure (FYM) increases SOC whereas reduces soil bulk density (BD) (Rasool et, al. 2008). Introduction of inorganic fertilizers along with low cost have largely replaced application of organic manure. (Sarkar et, al. 2003) stated that application of Inorganic fertilizer alone increased the BD.

A decrease in SOC leads to a decrease in soil's structural stability (Paz, 2002; Le and Arrouays, 1997; Bostik et, al. 2007). Also restoration of SOC in arable lands represents a potential sink for atmospheric CO_2 (Lal and Kimble, 1997). Agricultural utilization of organic materials, particularly farmyard manure (FYM) has been a rather common traditional practice Shen et, al. 1997), as it enhances the soil organic C level, which has direct and indirect effect on soil physical properties Sarkar et,al. 1988; Lado et, al. 2004). The inorganic fertilizers affect soil physical environment by increasing the above ground and root biomass due to immediate supply of plant nutrients in sufficient quantities (Lopez et, al. 1990). This in turn increases the soil organic matter content (Hynes and naidu, 1998; Bostik et, al. 2007; Sarkar et, al. 2003). Application of inorganic fertilizers alone decreased the stability of macro-aggregates and moisture retention capacity but increased the bulk density (Sarkar et, al. 2003; RAsool et, al. 2008) observed that balanced inorganic fertilization in rice, wheat system in a sandy loam soil improved the mean weight diameter of aggregates, total porosity and water holding capacity of soils. However, (Sheeba and kumarswamy, 2001) did not observe any effect of inorganic fertilizers on soil physical properties in a sandy loam soil. (Schjonning et, al. 2008) did not observe any effect of inorganic fertilization on soil hydraulic conductivity in the plough layer of sandy loam.

MATERIALS AND METHODS

Study was conducted in Raichur a district head quarter located in the northern region of Karnataka state (16022'32.38"N 77021'38.50"E), which is drought prone and falls in the arid tract of the India. The climate of the district is characterized by dryness for the major part of the year and a very hot summer.

Soils Used

A preliminary survey was carried out in different locations in and around Raichur, to select the soil samples for the study. Four soils namely black cotton, marshy, red and mountainous soil were taken from different locations by removing the top 5cm soil with ten samples from each location. Such of the collected samples were analyzed for particle size, field density and SOC as depicted in Walkely and Black (1934)

Soil Amendments

Flyash: Ash produced during combustion of coal, combustion has certain amount of loss on ignition (LOI) value that speaks of the unburnt matter this will still retain its organic carbon content (L. C. Ram et al., 1999; Indrek et al., 2004).

Class “F” category procured from Raichur thermal Power plant of Karnataka, called Raichur Fly ash (RFA) was used in the study as a source of SOC and an amendment. Composition of Fly ash is given in Table 1

Bagasseash: Sugar cane Bagasse is an industrial solid waste obtained after having extracted the juice by crushing the sugar cane, it is used worldwide as fuel in the same sugar industry. The combustion yields ashes containing high amounts of unburnt matter, silicon and aluminum oxides as main components. Bagasse ash was obtained from the Core Green Sugar & fuels Pvt. Ltd. An Industry located in Yadgir, Karnataka, and composition of Bagasse ash is given in Table 1.

Humus: It is the plant/animal residue that does not completely mineralize. A certain part of this residue is more or less resistant to microbial decomposition and remains for a period of time as an un-decomposed or in a somewhat modified state, and may even accumulate under certain conditions. Typical composition of humus is given in the Table 1 (Selman, 1986)

Pressmud: Pressmud or filter cake, a waste by-product from sugar factories, is a soft, spongy, amorphous and dark brown to brownish material which contains sugar, fiber, coagulated colloids, including cane wax, albuminoids, inorganic salts and soil particles. By virtue of the composition and high content of organic carbon, the usefulness of pressmud as a valuable organic manure has been reported by several workers (Nehra and Hooda, 2002; Ramaswamy, 1999). Sugar press residue (SPR) or pressmud is a potential source of major minerals as well as trace elements that can substitute chemical fertilizers. Press mud was obtained from the above said sugar industry. Composition of Press mud is given in Table 1

Table 1: Composition of Amendments

Constituents	Flyash %	Bagasseash %	Constituents	Humus %	Constituents	Pressmud % (Except pH)
SiO_2	61.10	78.34	Water soluble fraction	7	pH	4.95
Al_2O_3	28.00	08.55	Hemicelluloses	18.52	Total Solids	27.87
TiO_2	1.30	1.07	Cellulose	11.44	Volatile Solids	84.00
Fe_2O_3	4.20	3.61	Lignin	47.64	C.O.D	117.60
MgO	0.80	-	Protein	10.06	B.O.D	22.20
CaO	1.7	2.15	Ether-soluble fraction	5.34	OM	84.12
K_2O	0.18	3.46	pH	5.6	N	1.75
Na_2O	0.18	0.12	SOM	0.83	P	0.65
LOI	2.40	7.42	SOC	0.28	K	0.28
SOM	0.89	0.85			Na	0.18
SOC	0.3	0.29			Ca	2.7
					SOM	0.71
					SOC	0.24

Particle Size Analysis of Soils and Amendments

Sieve analysis was performed for all the collected soil samples as per IS: 460-1962 and grouped accordingly in soil class. BC soil was clayey sand with high plasticity, having 38% sand and 62% silt & clay. Red soil was clayey sand with intermediate plasticity, having 41% sand and 59% silt & clay. Mountainous soil was silty sand with low plasticity, having 42% sand and 58% silt & clay and marshy soil was non Plastic, with 77% sand and 23% silt & clay.

Similarly Bagasseash particles were uniform non-granular and average particle sizes ranged between 7 µm to 12 µm, Fly ash had 1% clay, 12% of silt and 87% of sand content. Pressmud was coarser than rest of the amendments with its particle size ranging from 0.1µ to 1mm (20%), 1mm to 10mm (80%). Humus had 38% of fine sand fraction, 35% silt

sized fraction and 27% clay sized fraction.

Test Procedure

Soil columns with dimensions 10 cm diameter and 30 cm length were fabricated by acrylic tubes and were then packed with the collected soil samples to their respective densities. The study was carried out in three phases based on the mode of application of SOC to soil as explained below.

Phase I

Soil-amendment combinations were individually assessed for their threshold SOC limits (based on obtained highest Water Holding Capacities) by replacing 0 to 40% volumes of soil with waste (SOC) and blending it with the top 15cm soil of the column, which resulted in 0.09 -0.55gm/gm with humus, 0.1-0.62 gm/gm with bagasseash, 0.2-1.19 gm/gm with pressmud and 0.08-0.5 gm/gm with flyash for BC soil. For red soil it was 0.07 -0.39gm/gm with humus, 0.07-0.45 gm/gm with bagasseash, 0.14-0.86 gm/gm with pressmud and 0.06-0.36 gm/gm with flyash.

For marshy soil it was 0.07 -0.41gm/gm with humus, 0.08-0.47 gm/gm with bagasseash, 0.15-0.9 gm/gm with pressmud and 0.06-0.38 gm/gm with flyash. For mountainous soil it was 0.08 gm/gm -0.47gm/gm with humus, 0.09-0.53 gm/gm with bagasseash, 0.17-1.02 gm/gm with pressmud and 0.07-0.42 gm/gm with flyash.

Phase II

Soil-amendment combinations were individually assessed for their threshold SOC limits by replacing 0 to 70% volumes of soil with waste (SOC) and blending it with the complete soil of the column, which resulted in 0.09 -1.92gm/gm with humus, 0.1-2.18 gm/gm with bagasseash, 0.2- 4.18 gm/gm with pressmud and 0.08-1.74 gm/gm with flyash for BC soil. For red soil it was 0.07 -1.37gm/gm with humus, 0.07-1.56 gm/gm with bagasseash, 0.14-2.99 gm/gm with pressmud and 0.06-1.25 gm/gm with flyash. For marshy soil it was 0.07 -1.45gm/gm with humus, 0.08-1.65 gm/gm with bagasseash, 0.15-3.16 gm/gm with pressmud and 0.06-1.32gm/gm with flyash. For mountainous soil it was 0.08 gm/gm -1.63gm/gm with humus, 0.09-1.86 gm/gm with bagasseash, 0.17-3.57 gm/gm with pressmud and 0.07-1.49 gm/gm with flyash.

Phase III

This phase was similar to phase II with the only difference that amendments were just stacked at top without blending with soil.

Porosity

The space occupied by air and water, between the particles in a given volume of soil are called pore spaces. The percentage of soil volume occupied by pore space or by inter-particle spaces is called porosity of the soil. It depends upon the texture and structure, compactness and organic content of the soil. Porosity of the soil increases with the increase in the percentage of organic matter content in the soil. Porosity of soil also decreases with reduced dimension of soil particles and increased depth of the soil.

$$\text{Porosity}(\%) = 1 - \frac{\text{Bulk Density}}{2.65}$$

Determination of Infiltration

A channel of 20cm X 60 cm X 15cm was prepared with facility of a free board as shown in Figure 1 and the samples (control and amended soils) were placed in compartments such that the respective field densities are achieved and

the setup was saturated and kept overnight. Water was then made to flow in the channel and the arrangements were made to collect the runoff water separately from both the compartments at the exit; also the infiltrated water was collected separately from the bottom of both the compartments from the base. Such of the collected volumes were quantified.

Figure 1: Experimental Setup for Determination of Infiltration

RESULT AND DISCUSSIONS

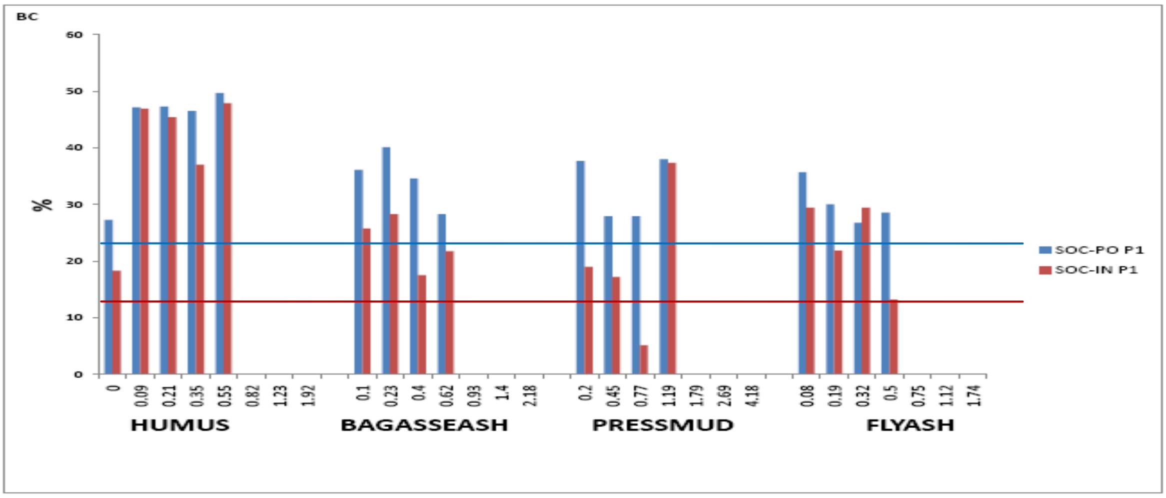

Figure 1a: SOC vs Porosity & Infiltration on BC Soil @ Phase I

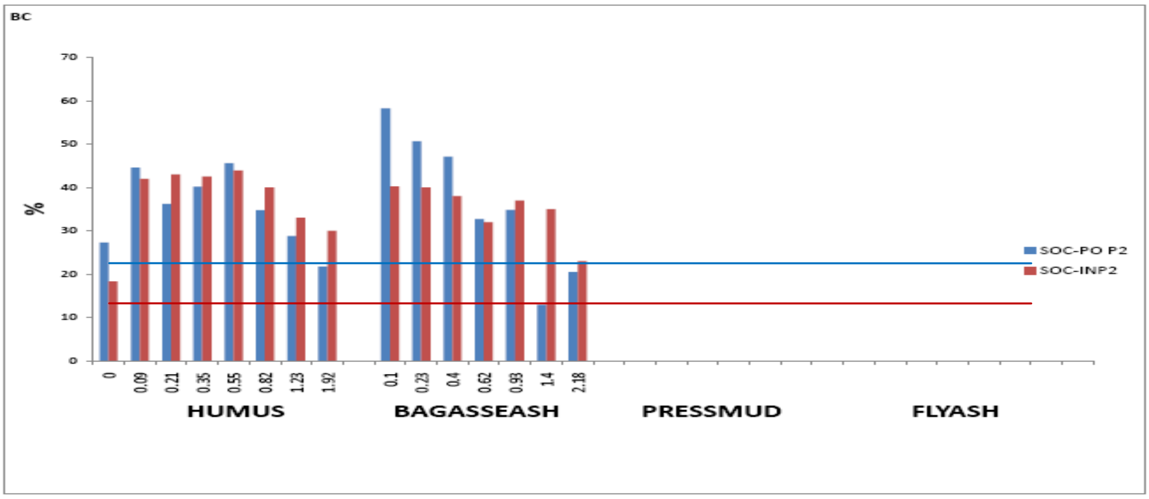

Figure 1b: SOC vs Porosity & Infiltration on BC Soil @ Phase II

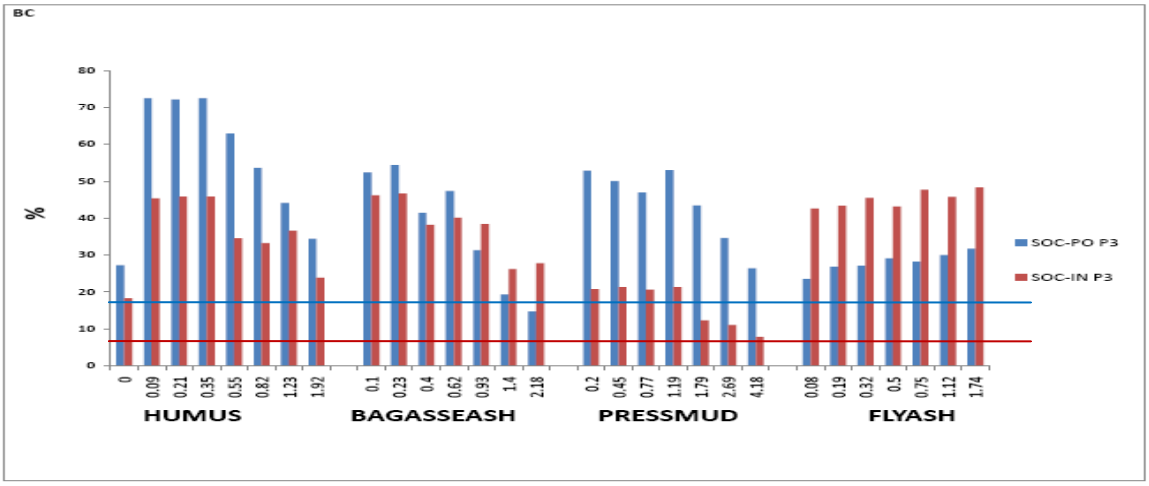

Figure 1c: SOC Vs Porosity & Infiltration on BC Soil @ Phase III

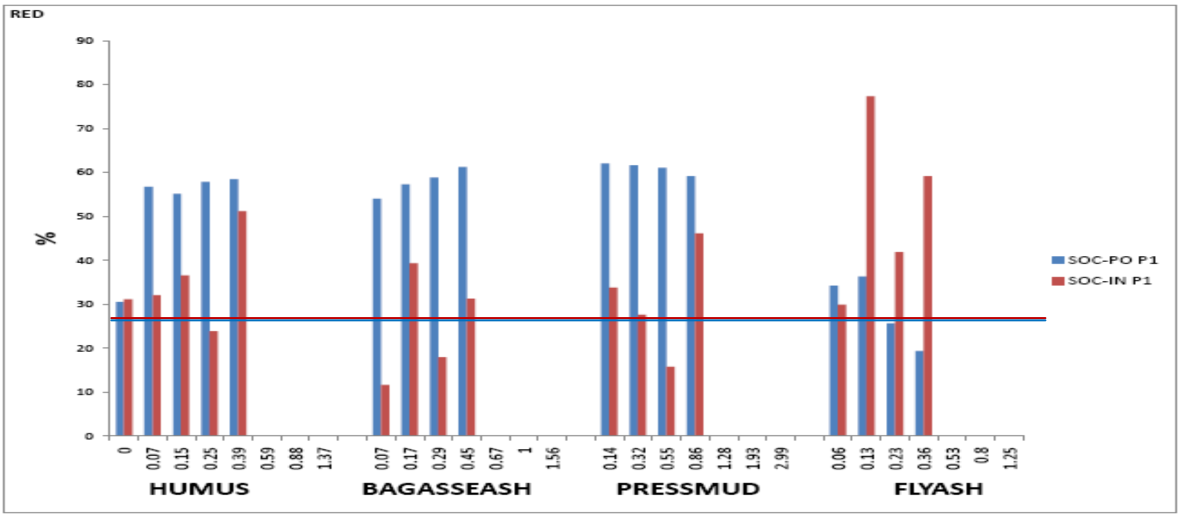

Figure 2a: SOC vs Porosity & Infiltration on Red Soil @ Phase I

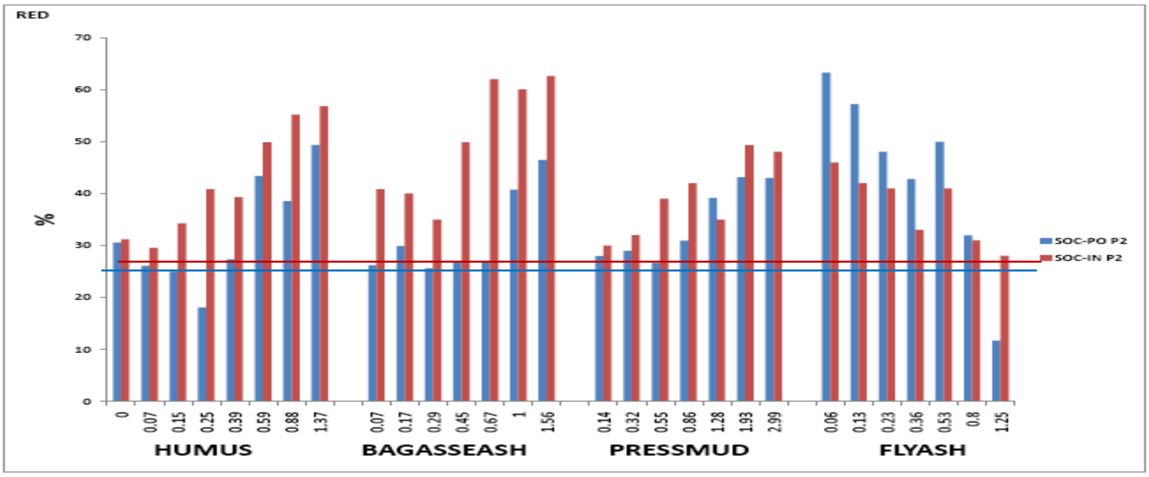

Figure 2b: SOC vs Porosity & Infiltration on Red Soil @ Phase II

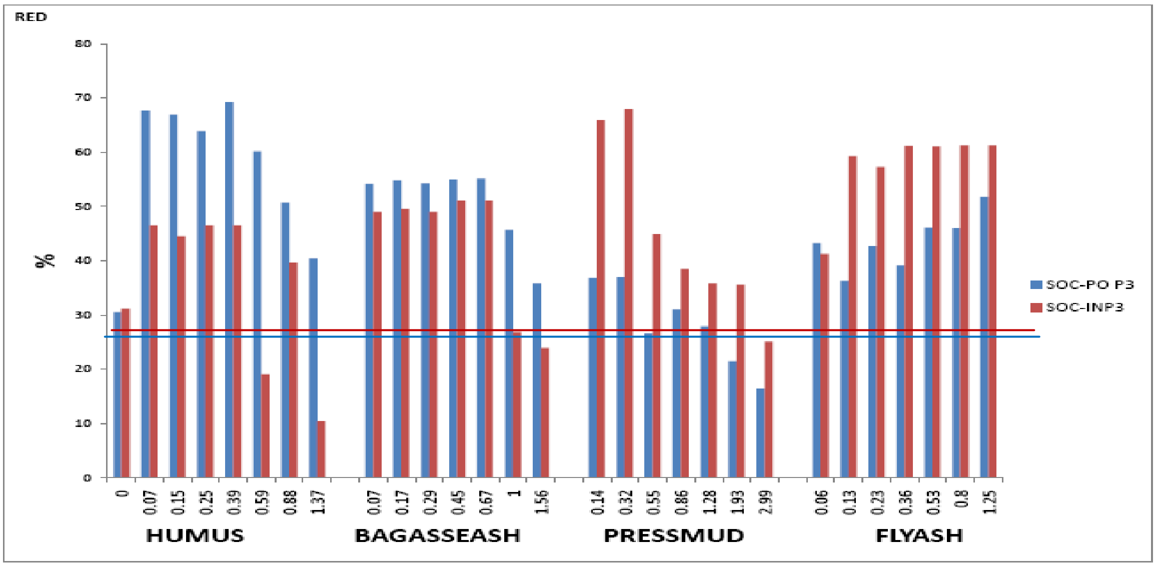

Figure 2c: SOC vs Porosity & Infiltration on Red Soil @Phase III

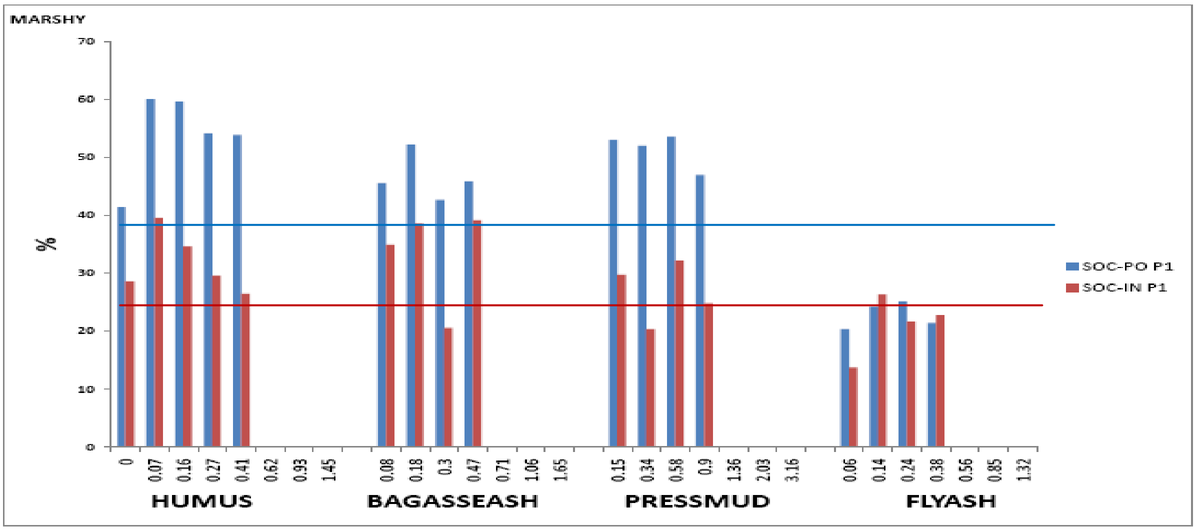

Figure 3a: SOC vs Porosity & Infiltration on Marshy Soil @ Phase I

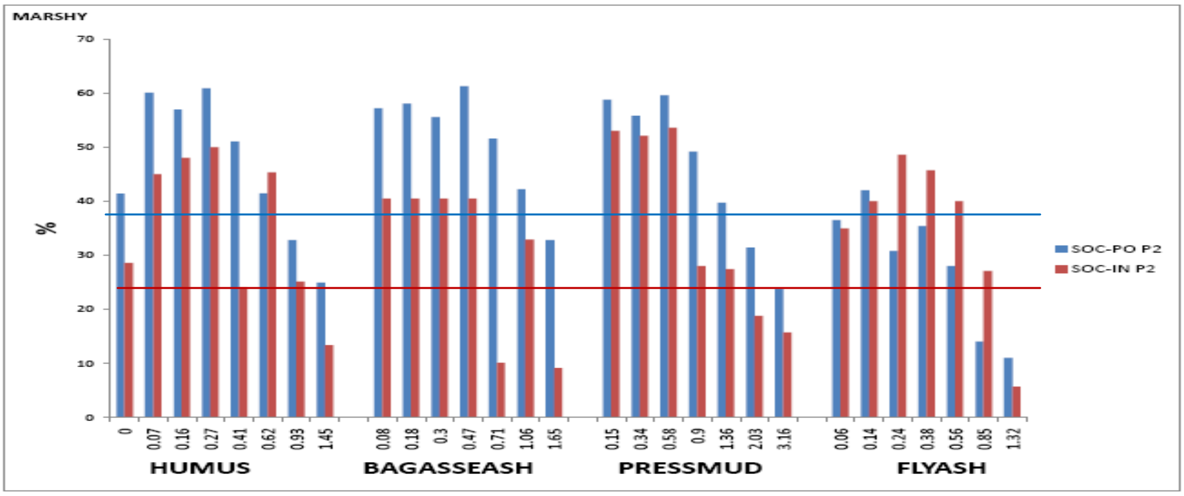

Figure 3b: SOC vs Porosity & Infiltration on Marshy Soil @ Phase II

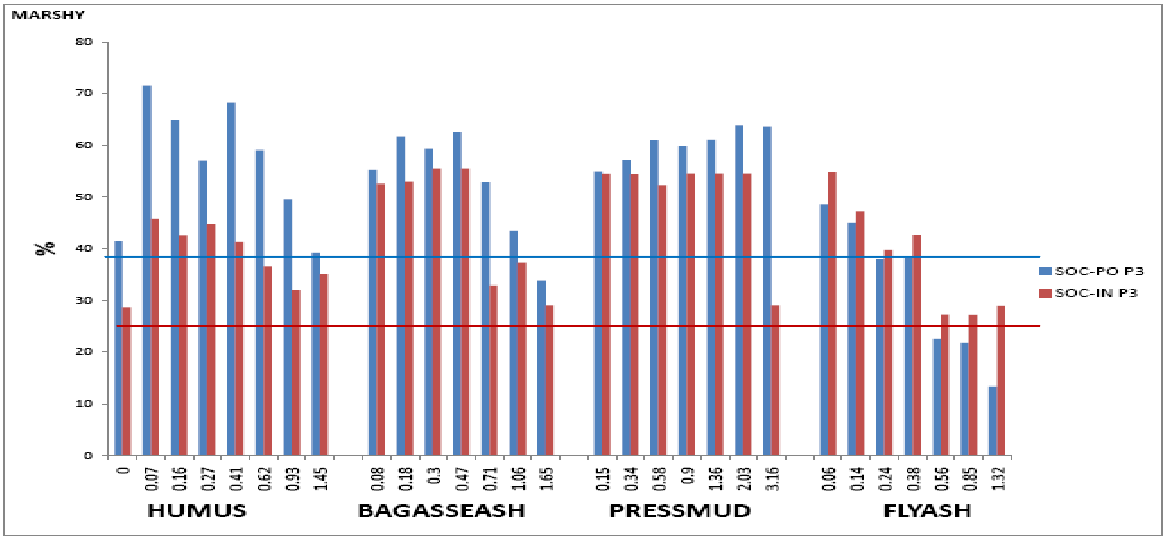

Figure 3c: SOC vs Porosity & Infiltration on Marshy Soil@ Phase III

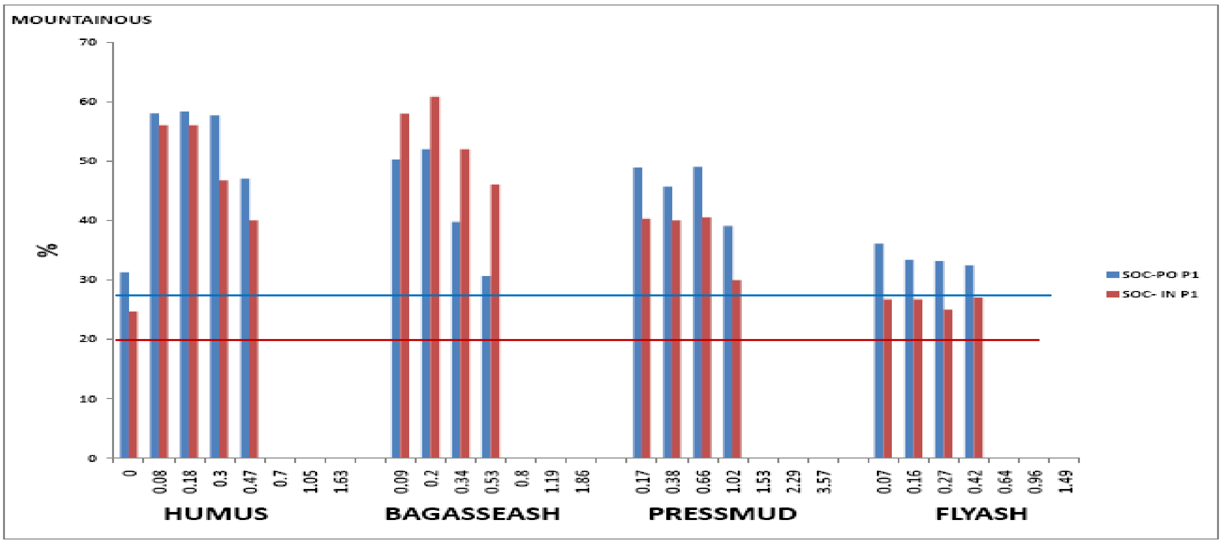

Figure 4a: SOC vs Porosity & Infiltration on Mountainous Soil @ Phase I

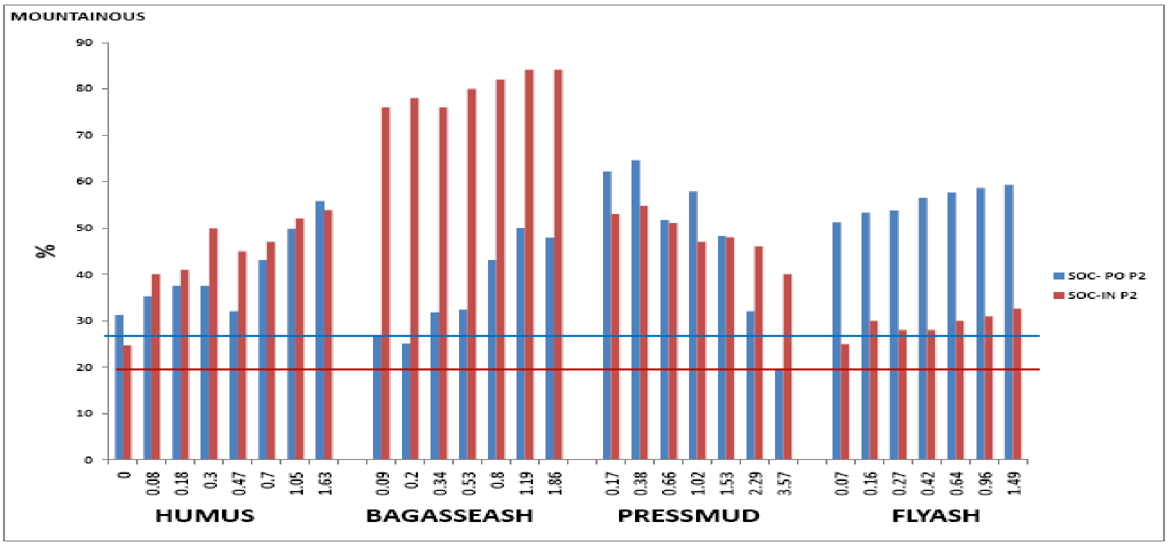

Figure 4b: SOC vs Porosity & Infiltration on Mountainous Soil @ Phase II

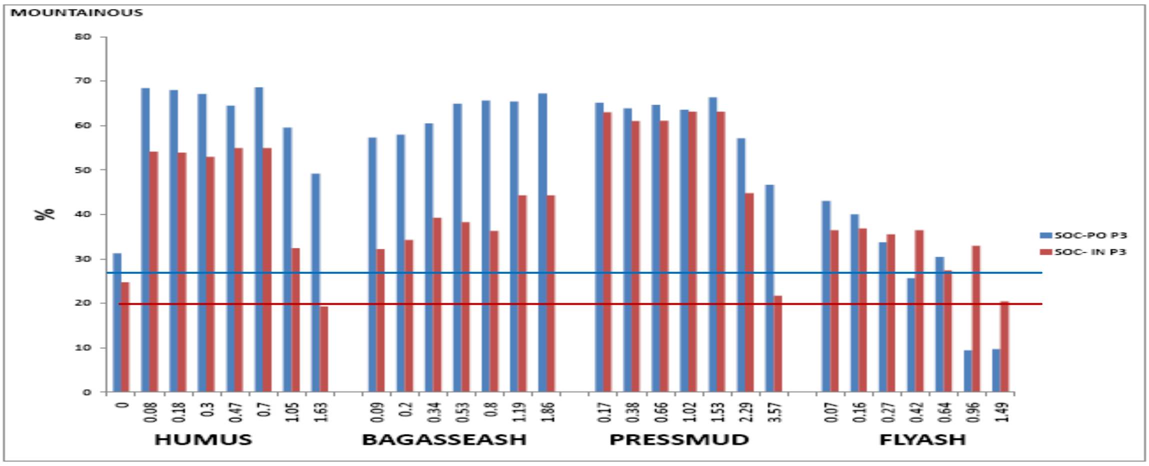

Figure 4c: SOC vs Porosity & Infiltration on Mountainous Soil@ Phase III

Porosity

BC Soil: In phase I, humus increased Porosity for all inputs. Increment was up to 1.8 times the control. Bagasseash increased porosity by 1.5 times, however increment was varying. Pressmud enhanced porosity by 1.4 times increment in SOC increased porosity, while flyash increased at the scanty input, the porosity was negatively linked with SOC. as seen in Figure 1a.

In phase II humus enhanced 1.5 times the porosity, while bagasseash doubled as seen in Figure 1b.

In phase III humus increased porosity by 2.6 times, while bagasseash and pressmud doubled. Enhancement of porosity by flyash amendment was very meager. As seen in 1c.

Red Soil: In phase I all the amendments except flyash doubled porosity while flyash improved a very little as seen in Figure 2a.

In phase II only flyash doubled porosity in comparison with the control, while the rest enhanced by 1.5 times, as seen in Figure 2b. In phase III humus and bagasseash doubled porosity, flyash enhanced 1.7 times while pressmud enhanced meager, as seen in figure 2c.

Marshy Soil: In phase I except flyash all the amendments improved both porosity 3a. All the amendments except flyash responded well in amplifying porosity for phase II & III in comparison with the control as observed I Figure 3 b & c.

Mountainous Soil: Humus bagasseash and pressmud equally performed better for porosity while flyash scarcely enhanced porosity in phase I as seen in Figure 4a. Performance of phase I repeated in phase II as seen in Figure 4b. For phase III except flyash all the amendment improved infiltration as seen in figure 4c.

Humus performed superior in amplifying porosity of all the soils in comparison with rest. It promotes total porosity of the soil as the microbial decomposition products of organic manures such as polysaccharides and bacterial gums act as soil particle binding agents. These binding agents decrease the bulk density of the soil by improving soil aggregation and hence increase the porosity. Bagasseash and pressmud enhanced soil porosity because they physically formed the clusters of aggregates by their rough textured micro structure which physically arrested the fines from motion, thus forming the stable structural matrix. Compared to other amendments flyash performed scantier than the rest in enhancing porosity for all the soils except red where it performed better, this is because increases in organic matter and clay content caused a relatively larger decrease in soil bulk density. Compared to control, porosities of all the soil

amendment combinations increased because of the reduction in BD related to the mixing of soil with less dense organic material, resulting in better aggregation and a consequent increase in volume of micropores.

Flyash showed little compatibility with all the soils except red soil this primarily due to, changes in total porosity as well as modifications in pore size distribution leading to decreased micro pores. Mode of blend even had its influence in enhancing porosity it was phase III for BC, mountainous and marshy. For red soil it was phase I that enhanced porosity.

Infiltration

BC Soil: In phase I, humus and pressmud increased infiltration for all inputs. Increment was double the control. Bagasseash increased porosity by 1.5 times, however increment was varying. flyash enhanced porosity by 1.6 times increment in SOC decreased porosity, as seen in Figure 1a. In phase II humus and bagasseash doubled in comparison with the control, as seen in Figure 1b. In phase III pressmud hardly increased infiltration, while the rest enhanced by 2.6 times, as seen in 1c.

Red Soil: In phase I flyash enhanced infiltration by 2.5 times, while humus enhanced by 1.5 times. Bagasseash and pressmud had no role in increasing infiltration as seen in Figure 2a. In phase II humus and bagasseash doubled infiltration, while flyash and pressmud increased by 1.5 times as seen in Figure 2b.

In phase III pressmud and flyash doubled infiltration, humus and bagasseash enhanced 1.5 times, as seen in figure 2c.

Marshy Soil: In phase I except flyash all the amendments improved infiltration as observed in Figure 3a.

All the amendments responded well in amplifying infiltration for phase II & III in comparison with the control as observed in Figure 3 b & c.

Mountainous Soil: Humus and bagasseash doubled infiltration in comparison with control. Pressmud increased by 1.5 times, there was hardly any improvement in infiltration when amended with flyash as seen in Figure equally performed better for porosity while flyash scarcely enhanced porosity in phase I as seen in Figure 4a. In phase II bagasseash enhanced infiltration by 3.5 times, while humus and pressmud doubled, while flyash increased infiltration by only 1.3 times as seen in 4b.

For phase III flyash improved infiltration by 1.5 times, while the rest doubled in comparison with the control as seen in figure 4c.

Performance of humus was not pronounced in infiltration this is because of shift in pore size distribution, this increases the tension required for pore drainage. Also the other factor may be at high water supply, aggregate destruction might have occurred (clogging of macro pores), silt-up and caking of the soil. Among other components the aggregate degradation is promoted by swelling and air explosion. At air explosion the air in the aggregates is compressed by infiltrating water as a consequence the aggregates burst as soon as the cohesive power is surpassed. Zhang and Hartge (1992) proved that air explosion and swelling has a far stronger effect the faster the water enters the aggregates. The infiltration velocity is reduced by organic matter as it reduces the moistening of the aggregates. The effectiveness of organic matter increases with an increasing humification degree of the organic material. Except mountainous soil fly ash performed better in improving infiltration of the soils.

CONCLUSIONS

A series of experiments were conducted to find the effect of organic carbon on porosity and infiltration of arid soils using various wastes as source of SOC. Channel studies were carried for the analyses of infiltration volumes for each

soil amendment combination. There exists a definite threshold limit of SOC for the soil amendment combination below and beyond which no significant gains in porosity and infiltration be seen. Mode of application significantly affected porosity and infiltration. Humus proved the best amongst the amendments in improving the porosities of the arid soils. Amending the arid soils improves the structure of the soil. Collective role of organic carbon, microstructure of soil as well as amendments and the mode of blend influenced the porosity and infiltration. Utilizing the organic wastes as amendments can be a better alternative to waste handling, which helps to maintain the soil health thereby facilitating proper soil management.

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